

**MINSITRY OF NATURAL RESOURCES AND
ENVIRONMENT**

**VIETNAM INSTITUTE OF METEOROLOGY,
HYDROLOGY AND CLIMATE CHANGE**

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**DEVELOPING A SOCIO-ECONOMIC CLIMATE
CHANGE IMPACT ASSESSMENT MODEL FOR
THE CITY OF DA NANG**

Specialization area: METEOROLOGY AND CLIMATOLOGY
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ABSTRACT OF EARTH SCIENCES DISSERTATION

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Hydrology and Climate Change

INTRODUCTION

1. Research demand of the study

On the national level as a whole, Vietnam is among the few nations heavily affected by climate change (CC). On the regional level, Da Nang, located in the Central Coastal Zone of Vietnam faces challenges due to the impacts of CC and Sea level rise (SLR).

On the other hand, climate change impacts on natural, environmental, and socio-economic conditions is becoming more apparent. This leads to an urgency in establishing a methodology (framework) to assess the impacts of climate change on natural and socio-economic systems and assess the vulnerability to climate change in order to propose adaptation measures. Therefore, the doctoral candidate chooses the thesis title to be: “Developing a socio-economic climate change impact assessment model for the city of Da Nang”

2. Research objectives and contributions

2.1. Research objectives

- + Establish a climate change impact and vulnerability assessment model for the city of Da Nang;

- + Quantitatively determine the impacts and vulnerability of climate change and sea level rise for selected socio-economic sectors in Da Nang.

2.2. New contributions

- + Quantitatively determined the impacts of climate change: flooding in agriculture, industry, transportation; yield and growth changes of paddy rice and maize in agriculture;

- + Quantitatively determined the vulnerability to climate change of selected socio-economic sectors.

3. Research subjects and scope

3.1. Research subjects

The research subjects in the thesis includes selected climate and natural disaster components (temperature, precipitation, flooding, and salinity intrusion) and sectors that are affected by climate change, including: water resources, agriculture, industry, urban, transportation and other socio-economic sectors.

3.2. Research scope

3.2.1. Temporal scope: The thesis is completed between 2012 and 2015;

3.2.2. Spatial scope: The city of Da Nang;

4. Structure of the thesis

The thesis is structured as follows:

Introduction: Research demand of the thesis, research objectives, research subjects, and research scope

Chapter 1: Literature review of climate change impacts on different sectors and vulnerability;

Chapter 2: Climate change impact assessment and vulnerability analysis methods;

Chapter 3: Assessing climate change impact and vulnerability for Da Nang city under climate change .

Conclusion and recommendations

CHAPTER 1 LITERATURE REVIEW OF CLIMATE CHANGE IMPACTS ON DIFFERENT SECTORS AND VULNERABILITY

1.1. State-of-the-art of climate change impact assessments internationally and in Vietnam

There is a large amount of research in the world on climate change impact assessment. These studies have a varying degree of

scales from large to small and focuses on all socio-economic and environment sectors. The area where much research effort is focused includes agriculture, forestry, aquaculture, human health, environment, water resources, energy, industry, etc.

There also exist a large amount of research assessing climate change and sea level rise impacts in Vietnam for various socio-economic sectors for the different regions. These studies are carried out by governmental organizations, research institutes, organizations within the Vietnam Union of Science and Technology as well as international organizations and non-governmental organizations.

Earlier researches focuses on studying climate change awareness and analyzing climate change trends based on observed data. Later researches have put more of an emphasis on assessing climate change impacts on socio-economic sectors as well as other natural sectors for different regions. Moreover, there is a large number of research which have proposed adaptation responses to climate change for specific locations.

1.2. State-of-the-art of vulnerability analysis

Researches globally:

+ There is a varying degree of approaches proposed and developed to assess vulnerability due to climate change based on food security, poverty, sustainable livelihood and other methods according to IPCC to assess vulnerability at the community level.

+ There are 4 main components in climate change studies: 1) theoretical models and framework in understanding vulnerability and the applicability of those models; 2) assessing vulnerability; 3) vulnerability scale and developing indices; 4) vulnerability data and

mapping.

+ There is no one suitable method for all regions, each approaches has to be individually tailored by specific information and suitable for a specific region, planning, period, human resources and available data.

+ There is a large number of approaches and tools but limited number of methods that could be widely applicable to different regions.

In Vietnam, starting from the early 2000, there has been studies on assessing vulnerability for different sectors. These studies used methods which are community based, scenario based, top-down approaches to determine vulnerability and adaptive capacity to climate change. These studies have also presented vulnerability maps, vulnerability level due to climate change and sea level rise and provided the foundation to determine the overall impacts of climate change and sea level rise. However, research on vulnerability assessment in Vietnam is still limited in the scope without any studies on an overall impact of climate change on all different socio-economic sectors. The approaches used in previous studies is still limited due to its inability to quantify vulnerability to climate change in infrastructure, agriculture, industry, livelihood, etc. yet have been able to determine the key factors in assessing vulnerability

1.3. Natural conditions of Da Nang city

The city of Da Nang is a coastal Vietnames city of significant importance with a natural area of 1,255.53 km², in which land mass is approximately 950km² accounting for 0.38% landmass of Vietnam. Da Nang is located in the Central part of Vietnam, in the middle intersection of the North-South land transport route and act as

density of 3457 people/km², 20 times higher than that in rural areas. Gross Domestic Product (GDP) for Da Nang in 2012 is approximately 46, 368 billion Vietnam Dong and Da Nang has consistently been rank first nationally in its Competitiveness Index. Within the last years, Da Nang has invested heavily on infrastructure development, environmental improvement programs, social welfare increase and is “the city to be in” of Vietnam.

The Climate change and sea level rise scenario from the Ministry of Natural Resources and Environment published in 2012 showed that Da Nang is under a major threat from climate change.

CHAPTER 2. CLIMATE CHANGE IMPACT AND VULNERABILITY ASSESSMENT APPROACH

2.1. Climate change impact and vulnerability assessment model

Climate change impact and vulnerability assessment for Da Nang is undertaken through:

- + Analyzing the changing trend of climate features based on the Climate change and sea level rise scenarios published by the Ministry of Natural Resources and Environment in 2012.

- + Assess climate change impacts on selected sectors for Da Nang city. The assessment is done both quantitatively and qualitatively based on available data. Based on the fact that Da Nang is a coastal city frequently under the impact of flooding and salinity intrusion, sectors that are quantitatively assessed therefore, are also based on climate change scenarios for flooding and salinity intrusion. Additionally, agriculture also have a far reaching impact on other socio-economic sectors in the city, therefore, is also assessed in the thesis. Other areas where impacts are limited or not able to be assessed due to limited data such as forestry, healthcare, education,

etc. are qualitatively assessed to serve as a reference input for vulnerability assessment.

+ Vulnerability assessment based on the analysis of extreme climate features and impact assessment of various sectors based on the climate change scenarios combined with socio-economic planning of the relevant sectors.

From the aforementioned assessment, the doctoral candidate has successfully developed a framework for impact and vulnerability assessment due to climate change and sea level rise for Da Nang city (as shown in Figure 2.1).

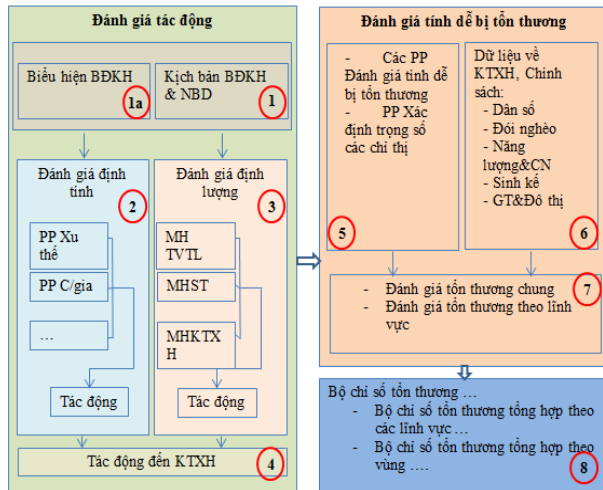


Figure 2.1 Model framework impact assessment procedures and vulnerable

2.2. Climate change research methodology

Climate change research methodology is understood as the method in which the signs of climate change are assessed. The thesis determines the sign of climate change through identifying the changing trend of climate variables. This is done through assessing the standard deviation (S) and S_r .

The speed of change is determined based on trend analysis. X and t are assessed as linear functions.

Based on the World Meteorological Organization published climate extreme indices in 2010, the doctoral candidate selects the following climate extreme indices: (1) maximum absolute temperature, (2) minimum absolute temperature, (3) sunny days, (4) extreme sunny days, (5) cold days, (6) extreme cold days, (7) days with extreme precipitation.

2.3. Climate change impact assessment methodology

The thesis has combined a wide range of methods to assess climate change and sea level rise impacts. In particular, numerical models were used to determine flood and salinity intrusion maps for Da Nang. In addition, other models were used to determine changes in yield and growth time for selected agricultural crops in Da Nang.

2.3.1 Method to determine flood map due to climate change and sea level rise for Da Nang

Based on the river system, topography characteristics and hydro-meteorological data, climate change and sea level rise impact is assessed based on Figure 2.2. In that, the thesis have applied the MIKE NAM rainfall-runoff

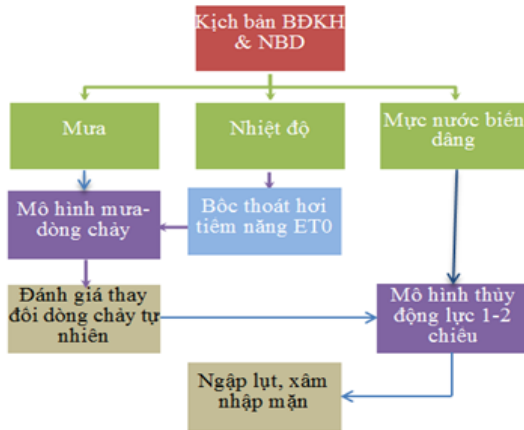


Figure 2.2. Block diagram of the climate change impact assessment to flooding and saltwater

model to assess the changes in natural stream flow and MIKE hydrodynamic model to determine flooding, and salinity intrusion. In addition, remote sensing and GIS tools were also utilized to visualize flooding and salinity intrusion results.

MIKE NAM model simulates the rainfall-runoff process for two sub basins namely the Thanh My and Nong Son. Input data includes precipitation data for Thanh My, Kham Duc, Hien, Nong Son, Son Tan, Tra My, Tien Phuoc, Que Son, Tam Ky, Da Nang and hydrological data for Thanh My and Nong Son stations. Model calibration and validation showed satisfactory NASH values. Therefore, the calibrated model could be used to simulate streamflow under climate change scenarios in the future.

Table 2.1 Calibrated model paramters for MIKE NAM

Station	F (km ²)	Parameter									Nash	
		U_{max}	L_{max}	CQ_{OF}	CK_{IF}	$CK_{1,2}$	T_{OF}	T_{IF}	TG	CK_{BF}	HC	KĐ
Nông Sơn	3155	14	131	0,544	580,1	33,1	0,648	0,16	0,117	1048	0,84	0,85
Thành Mỹ	1850	10,2	102	0,497	747	23,6	0,725	0,235	0,0145	1382	0,80	0,87

The MIKE 11 model was used to simulate hydrodynamic processes in the mainstream of the Vu Gia Thu Bon River, starting from Nong Son and Thanh My and the main sub-basins of the middle section and downstream of Vu Gia Thu Bon River Basin.

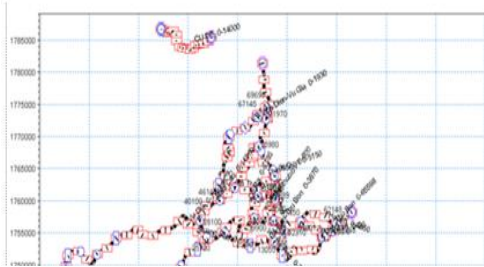


Figure 2.3. Hydraulic Network River flood season Vu Gia-ThuBon- Cu De" built in model Mike 11

Upper boundary conditions is restricted by Thanh My and Nong

Son hydrological stations, lower boundary conditions is determined by the water level at Han, Dai and Nam O estuaries. During calibration and validation, the lower boundary values were taken from observed data (for Son Tra) and accounted by a conditional coefficient (Thu Bon). For the climate change scenarios, lower boundary conditions were taken from the sea level rise simulated results.

Table 2.2. Calibration and Validation of water level at hydrological stations

Station	River	Calibration (31/10-11/11/99)			Validation (01/11-07/11/96)		
		H_{tdmax}	H_{ttmax}	Sai số	H_{tdmax}	H_{ttmax}	Sai số
Ái Nghĩa	Vu Gia	10,27	10,390	0,120	9,78	9,88	0,1
Cầm Lệ	Vu Gia	3,77	3,695	0,075	2,28	2,46	0,18
Câu Lâu	Thu Bồn	5,23	5,364	0,134	4,44	4,60	0,16
Hội An	Hội An	3,21	3,187	0,023	2,57	2,34	0,23

Results showed that the difference between observed and calculated water level is within acceptable range. Therefore, the hydrodynamic model could be applied to determine flood in Da Nang under climate change.

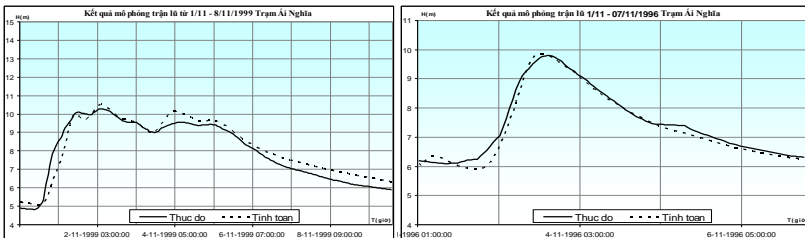


Figure 2.4 Results calibration verification process water levels at Ai Nghia

2.3.2 Climate change impact on crop assessment methodology

The thesis utilizes the Decision Support System for Agrotechnology Transfer (DSSAT). This is a tool which combines the effects of soil, type of crops, genes of crops, weather and cropping

technology and has been widely used.

Input data includes climate data for the time period 2008-2012, medium climate change scenario (B2) for the time period 2020-2100 at Da Nang station, Crop type (HT1 paddy rice, LVN25 maize) and agricultural production status as well as cropping land information was collected to parameterize, simulate the impacts of climate change on yield and growth time of paddy rice and maize in Da Nang.

Gene parameters (HT1 paddy rice, LVN25 maize) were calibrated, validated for the study area prior to simulation. On the basis of the assumption that the type of crops does not change in the future, cropping technology would remain the same. The main maize cropping calendar is the Summer-fall crop cycle while for paddy rice is the Winter-Spring and Summer-Fall cycles. Recorded yield at the local level were chosen to be compared with expected changes in the future.

2.4. Vulnerability assessment methodology

2.4.1 Method selection to determine vulnerability index

The thesis proposes one vulnerability index calculation method based on the general guideline from IPCC. The method is used to determine vulnerability of the natural system but also based on the risk management approach to determine the impacts of natural hazards (flooding, inundation, and sea level rise) on human systems. Afterwards, the vulnerability index is analyzed and assessed so that adaptation measures for different sectors could be proposed.

The development of a vulnerability index is based on the overall assessment of changes in climate variables such as: changes in temperature and precipitation; sea level rise, and changes in other natural hazards especially flooding and salinity intrusion. From that,

information is then combined to develop a vulnerability index for the city of Da Nang.

2.4.2 Vulnerability index for Da Nang city methodology

❖ Selected area

The area selected is based on administrative borders, i.e. districts of Da Nang city, excluding Hoang Sa district. All in all there are 7 districts (Hai Chau, Thanh Khe, Son Tra, Ngu Hanh Son, Lien Chieu, Cam Le, and Hoa Vang district). The selection allows the determination of indices and applying the results for planning in Da Nang.

❖ Developing the coefficients

The thesis focuses on 3 areas: (1) social issues (population, poverty and livelihood), (2) industry and energy; (3) urban and transportation

The initial phase assesses the three areas separately, both for the natural and social exposures. Each sector selected for each district were assessed as a function of vulnerability based on coefficients, afterwards, average relative baseline exposure is determined for each district. In the second phase, each district is then ranked based on its relative sensitivity to projected risks of simulated hydrological model results. Population growth could also be used to predict changes in the sensitivity coefficient. Results from climate models could show exposure in the future under climate change, could be used to predict changes in risk indices. In which, the area affected by each risk type could be used to estimate the number of people affected. Flood hazard map until 2030, 2050, 2070, and 2100 were used to predict the vulnerability in the future. The resulted climate change impact on agricultural crop yield and growth time were then used to determine

the coefficients for agriculture in the future.

❖ *Index standardization*

The thesis applied the Human Development Index (HDI) from UNDP to standardized the indices within the range of 0 to 1

❖ *Weight determination and vulnerability index calculation*

The uneven weight method from Iyengar & Sudarshan was used to determine the weight of each index and to calculate the vulnerability index. Each sector is selected based on 3 factors:

(1) Effect factors (E): including natural hazards such as storms, flooding, salinity intrusion, droughts, etc. and changes in climate extreme variables such as maximum temperature, minimum temperature, heavy rain, etc.

(2) Sensitivity factors (S), includes inundation area, area affected by salinity intrusion, population affected, main crop types yield and productivity, agricultural area, number of cattles, poultry, etc.

(3) Adaptation factors, including infrastructure such as transportation route length, number of durable housings, amount of equipment, electricity network, human resources, etc.

CHAPTER 3: EVALUATING THE IMPACT AND VULNERABILITY OF CLIMATE CHANGE AND SEA-LEVEL RISE FOR DANANG

3.1. Evaluating the signs of climate change in Danang city

The data includes temperature and precipitation measured at Danang station from 1961 to 2010. The analysis of the data shows:

Annual average temperature at Danang station has a slightly upward trend, volatility of monthly temperatures is stable, the highest is during winter and the lowest is during summer (Fig. 3.1), the variation and trend of the temperature fluctuations for months are different. During the winter (January), the temperature has a slightly

upward trend, Sr index decreases; in contrast, temperature during the summer (July) has a downward trend with increasing Sr index for the last 20 years. In conclusion, the volatile fluctuation of temperature in Danang area has an upward trend for the summer while being more stable during the winter.

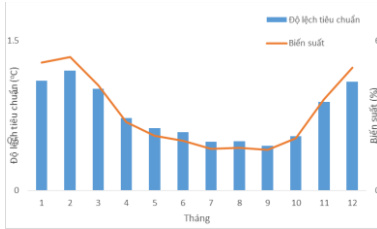


Figure 3.1: Standard deviation (S) and Sr of the temperature from 1961 to 2010

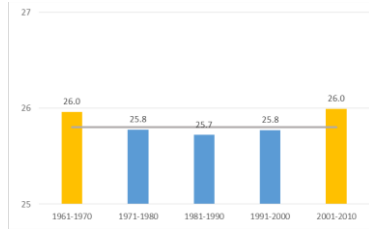


Figure 3.2: Characteristics of annual average temperature

Annual absolute highest temperature (T_{xx}) decreases, numbers of hot days, sunny and hot days (SU35), and severe hot days also have a downward trend. The absolute lowest temperature (T_{nn}) has an upward trend but with high volatility.

Annual precipitation also fluctuates over the decades. In the period of 1961 – 2012, Danang has higher precipitation within the 02 recent decades (Fig. 3.3). Danang's annual precipitation tends to increase, it decreases during the summer (July), winter (January) while increases during the spring (April), fall (October). The number of days with heavy rain also increases, maximum 1-day precipitation tends to decrease while maximum consecutive 5-day precipitation tends to increase.

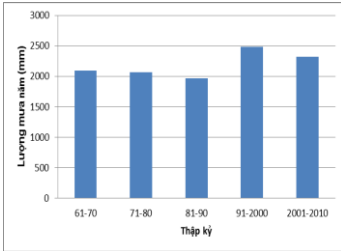


Figure 3.3: Decennial average precipitation

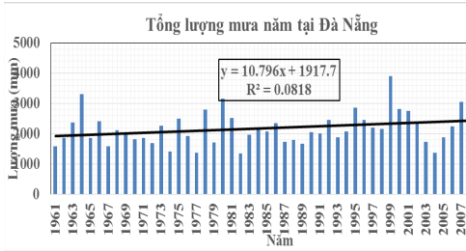


Figure 3.4: Changing trend of precipitation

3.2. Evaluating the impact of climate change and sea-level rise to industries in Danang city

Using the assessment methods for water resources mentioned in Chapter 2, this dissertation carefully evaluated the flood risks for each periods, flood levels then provided 1‰ and 4‰ salinity boundaries for Danang in the Medium emission scenario B2.

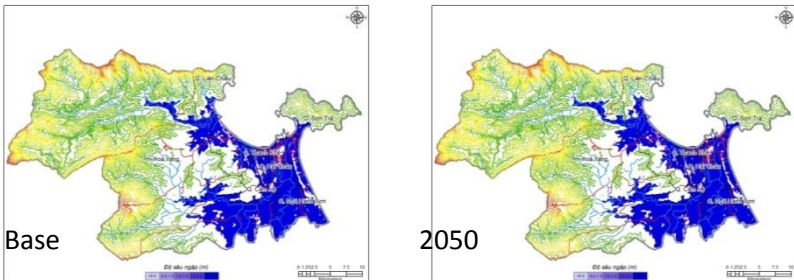


Figure 3.5: Map of flood risk caused by climate change and sea-level rise for each periods

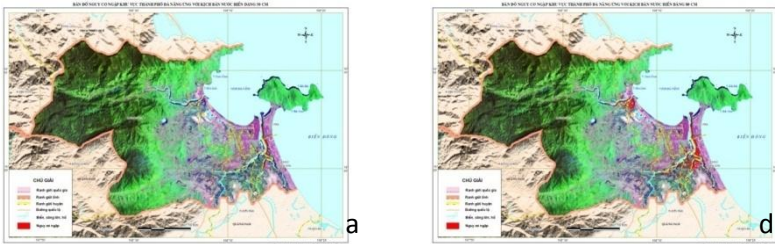


Figure 3.6: Map of flood risk corresponding to the NBD level a-50cm; d-80cm

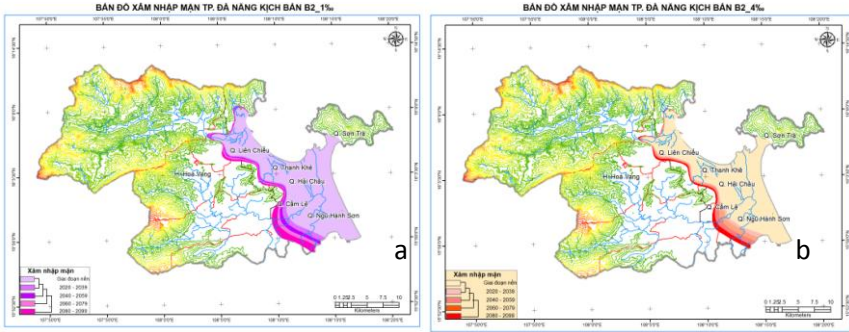


Figure 3.7: Salinity boundaries a-1‰ b-4‰

Based on the results, the researcher identified the area impacted by flood and salinization for agriculture, forestry, industrial and transportation.

Table 3.1: The percentage of area at risk of flood for districts (%)

Period/ District	Độ sâu ngập (m)	TK nền	Tk 2020	Tk 2030	TK 2050	Tk 2070	TK 2100
Hai Chau	<0.5	17,2	29,2	28,3	20,1	17,0	17,6
	0.5-1	33,6	31,0	30,3	36,7	40,9	26,4
	>1	41,4	44,0	44,2	44,7	45,3	47,4
Thanh Khe	<0.5	11,7	3,8	3,5	4,1	4,2	4,6
	0.5-1	28,9	22,1	20,4	15,3	12,4	9,1
	>1	61,4	63,0	63,2	63,8	64,3	64,5
Son Tra	<0.5	7,5	6,0	7,1	6,0	4,9	3,5
	0.5-1	10,7	11,4	10,6	10,5	10,2	8,5
	>1	38,2	38,6	38,7	38,9	39,3	39,9
Ngu Hanh Son	<0.5	12,2	12,9	13,0	12,2	12,7	12,4
	0.5-1	18,54	17,9	18,2	18,0	16,2	16,3
	>1	35,7	36,8	36,9	37,1	37,5	38,1
Lien Chieu	<0.5	22,1	13,6	13,7	13,5	14,2	15,9
	0.5-1	41,4	36,2	37,0	30,9	29,6	26,5
	>1	41,4	45,8	45,7	46,0	46,4	47,3
Cam Le	<0.5	12,9	14,5	14,5	14,7	15,0	13,6
	0.5-1	23,9	24,1	23,2	20,9	20,6	19,6
	>1	50,0	58,3	59,9	61,5	62,1	66,9
Hoa Vang	<0.5	12,4	20,1	20,6	15,0	16,0	17,7
	0.5-1	22,4	28,1	28,6	25,2	27,4	22,6
	>1	32,0	32,5	32,6	32,6	32,7	32,8

In regard of agriculture, the dissertation used the DSSAT model to calculate the impact of climate change to the productivity and output of rice and maize in Danang:

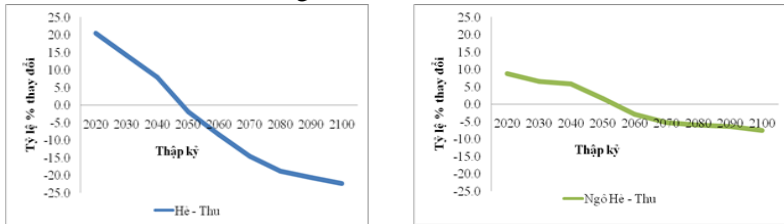


Figure 3.8: The change in productivity of rice in the Winter – Spring season (a) and maize compared to 2012

The productivity of rice in the Winter – Spring season from 2020 – 2100 will decrease on an average of 3,1% per year, and the productivity in the Summer – Fall season will decrease on an average of 4,9% per year. For maize, there is an average 0,6% decrease per year in productivity.

By 2100, the growth duration of rice type HT1 can be shortened about 7 days in the Winter – Spring season and 14 days for the Summer – Fall season. The average growth duration of rice type HT1 can be shortened by 8 days. The growth duration of maize type LVN25 can be cut down by 16 days by 2100.

The dissertation also assesses the impact of climate change and sea-level rise to other sectors such as forestry, population, health, tourism... However, the impacts aren't significant but they are still analyzed to assess the vulnerability.

3.3. Assess the vulnerability for sectors in Danang city

The method of Iyengar & Sudarshan mentioned in chapter will be used to calculate the vulnerability index for Danang city.

3.3.1. The vulnerability index for social sector

The dissertation proposed 8 indicators of climate change impacts, 26 sensitivity indicators and 20 indicators for responding solution in social sector. These indicators of impact are statistics from actual measured data and interpolated for each research area, parameters will be extracted from the scenarios of climate change and sea-level rise.

The sensitivity indicators are from the evaluated results of flood, salinization and change in productivity, growth duration of crops; statistical yearbooks and planning for economic and social development. The indicators for responding solutions were analyzed from the measure of the capacity of human resources, economic viability, livelihood measures and social capacities

Table 3.2. The vulnerability index for the social sector

Period	Hai Chau	Thanh Khe	Son Tra	Ngu Hanh Son	Lien Chieu	Cam Le	Hoa Vang
Nền	0.472	0.435	0.472	0.579	0.451	0.508	0.483
2020	0.526	0.465	0.498	0.568	0.473	0.523	0.514
2030	0.533	0.436	0.490	0.549	0.455	0.514	0.517
2050	0.460	0.482	0.580	0.442	0.484	0.506	0.526
2100	0.514	0.471	0.468	0.544	0.426	0.493	0.469

The climate change vulnerability index of Danang districts in the social sector is in the range of 0.4 to 0.6 which is the average level of damage.

3.3.2 The vulnerability index for energy and industry sector

There are also 8 indicators of climate change impacts. The sensitivity indicators include: the area of industrial land impacted by flood, the number of factory workers and private companies. The indicators of resilience are used to evaluate in the future period and are determined on the basis of each district's development planning: Number of schools, number of families using electricity, communication devices, and number of power stations.

Table 3.3. The vulnerability index for energy and industry sector

Period	Hai Chau	Thanh Khe	Son Tra	Ngu Hanh Son	Lien Chieu	Cam Le	Hoa Vang
Base	0.611	0.506	0.517	0.597	0.504	0.499	0.453
2020	0.610	0.508	0.511	0.572	0.543	0.518	0.490
2030	0.606	0.493	0.506	0.569	0.534	0.513	0.603
2050	0.515	0.499	0.574	0.485	0.468	0.488	0.633
2100	0.623	0.536	0.500	0.564	0.456	0.460	0.439

The results show that the vulnerability index of the energy and industry sector in Danang ranges within 0,4 - 0,65 which is on a medium level. However, Hai Chau and Hoa Vang district are at high level ($> 0,6$). These districts both have a large number of factories workers and private companies which leads to greater sensitivity than other areas.

3.3.3 The vulnerability index for transportation and urban sector

The sectors also have similar indicators of impacts. There are 11 sensitivity indicators: population, population density, the area of flood urban land, % of flooded roads, population affected by flood, sea-level rise, salinization. The resilience index (A) for transportation and urban sector includes: permanent roads, resilience of infrastructures – sewage system, electricity network.

Table 3.4. The vulnerability index for transportation and urban sector

Period	Hai Chau	Thanh Khe	Son Tra	Ngu Hanh Son	Lien Chieu	Cam Le	Hoa Vang
Base	0.634	0.754	0.607	0.694	0.635	0.744	0.558
2020	0.760	0.925	0.496	0.732	0.691	0.723	0.550
2030	0.721	0.906	0.476	0.688	0.571	0.691	0.767
2050	0.943	0.524	0.720	0.589	0.700	0.632	0.745
2100	0.723	0.889	0.491	0.719	0.599	0.700	0.606

The vulnerability index for these sectors are in the range of 0,4 – 0,95 which is in the high level. Thanh Khe district has the highest index in every period.

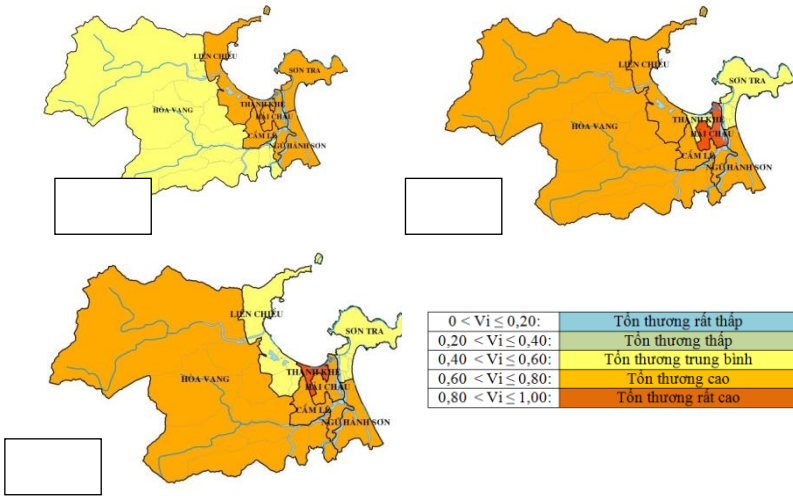


Figure 3.11. Map of vulnerability for transportation and urban sector

3.3.4 The climate change vulnerability index for Danang

Table 3.5. The vulnerability index for sectors

Sector	Hai Chau	Thanh Khe	Son Tra	Ngu Hanh Son	Lien Chieu	Cam Le	Hoa Vang
Social	0.501	0.458	0.502	0.537	0.458	0.509	0.502
Industry and energy	0.593	0.508	0.521	0.557	0.501	0.496	0.524
Transportation and urban	0.756	0.800	0.558	0.684	0.639	0.698	0.645

Overall, the majority of the results is in the medium level except for transportation and urban sector which is in the high level.

Table 3.6. The index and ranking of vulnerability for Danang from 2020 - 2100

Period	Hai Chau	Thanh Khe	Son Tra	Ngu Hanh Son	Lien Chieu	Cam Le	Hoa Vang
Base	0.572	0.565	0.532	0.623	0.530	0.584	0.498
2020	0.632	0.632	0.502	0.624	0.569	0.588	0.518
2030	0.620	0.612	0.491	0.602	0.520	0.573	0.629
2050	0.640	0.502	0.625	0.505	0.551	0.542	0.635
2100	0.620	0.632	0.486	0.609	0.494	0.551	0.505

Hai Chau, Thanh Khe and Ngu Hanh Son are the 03 districts with

vulnerability index at the high level. Lien Chieu and Cam Le are at the medium level. Extra resilience methods need to be implemented for Hai Chau, Thanh Khe and Ngu Hanh Son in the future in all sectors.

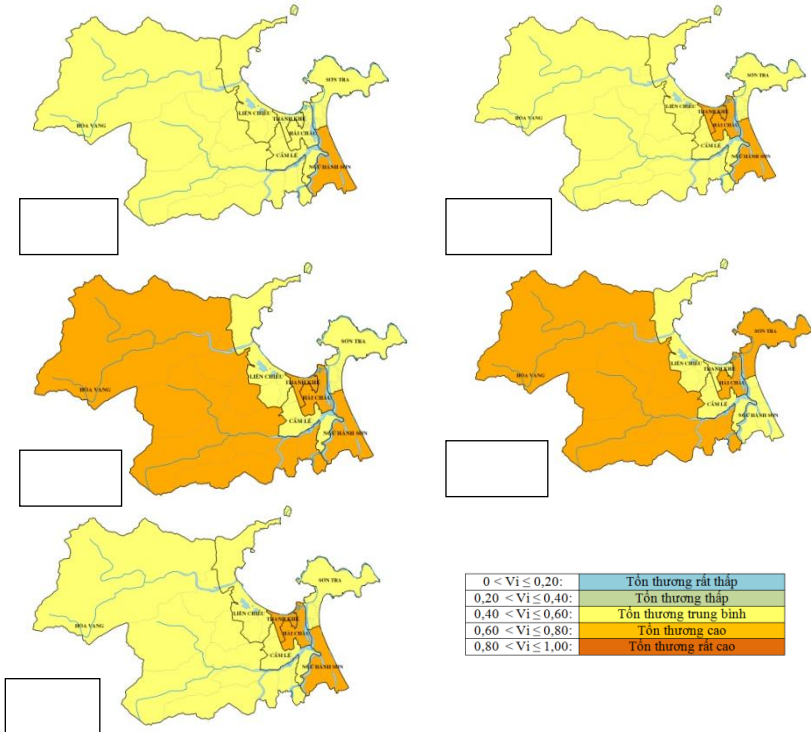


Figure 3.21. Map of vulnerability index for Danang

CONCLUSION AND PROPOSALS

Conclusion

The conclusions can be drawn from the outcome of the research:

1. The dissertation utilized research documents related to impact assessment of climate change and sea-level rise, vulnerability assessment methods. These are the scientific basis to evaluate the impact of climate change and sea-level rise, vulnerability for Danang city.

2. The dissertation analyzed the characteristics of climate change in Danang by using the series of temperature and precipitation observations from 1961-2010 and statistics of extreme climatic phenomena.

3. The dissertation evaluated the impact of climate change for the following sectors:

+ Water resource: The flow volume of currents tends to increase during flood season and decrease during drought season; flood and salinization have an upward trend in Danang. Based on the results from MIKE 11 model and GIS technology, the system of maps for flood and salinization for Danang has been created, it identifies the impacted area for each district, especially for heavily impacted coastal districts such as Son Tra, Ngu Hanh Son, Thanh Khe, Lien Chieu.

+ Agriculture: Identified the agricultural areas which are impacted by flood and evaluated the impact of climate change to the 02 main crops in Danang (rice, maize) using the DSSAT model. In summary, there is a decrease in productivity for rice in Winter - spring, Summer - Fall season and for maize in the future; growth duration will be shortened compared to the current duration.

+ Industry, energy, transportation and infrastructure sectors are

all impacted by climate change, sea-level rise; specific areas impacted by flood in the future have been identified.

+ Evaluated the impacts of climate change to other aspects such as forestry, population, tourism... However, these impacts weren't quantified but only analyzed to assess the vulnerability.

4. Based on the assessments, the vulnerability index has been calculated for districts in Danang in 03 aspects: society, energy and industry, transportation and urban with the following results:

+ Social aspects: The vulnerability for districts is at a medium level (0,4 -0,6) for the base period and for 2020, 2030, 2050, 2100. However, there is a variation between districts, the smallest index is in Lien Chieu, Thanh Khe and the highest is in Ngu Hanh Son. Hence, Ngu Hanh Son requires special attention to the measures to protect the community against climate change.

+ Energy and industry sector: The vulnerability index is within 0,4 - 0,65 which is at a medium level. Nevertheless, Hai Chau and Hoa Vang district have reached high level for a few periods. These districts have high number of businesses and factory workers hence higher vulnerability compared to other districts. Hoa Vang district is also a rural district with low-level infrastructures and weaker resilience. The planning for energy and industry sector must focus on upgrading the infrastructure for these districts to be capable of adapting to the impact of climate change.

+ Transportation and urban sector: The index is in the high level 0,4 - 0,95. Thanh Khe, Hai Chau district are the highest (0,6 - 0,95) for every periods, these districts also have more flooded traffic area compared to others. These districts not only require immediate attention but also require attention in future planning. Other districts

also have vulnerability index at high level, solutions to adapt to climate change need to be implemented to minimize the risk.

Limitations:

- Quantitative assessment wasn't available for a number of sectors such as population, health; forest fire...Also, a number of natural disasters wasn't mentioned.

- Iyengar-Sudarhan is the only method used to determine the index weight for E, S, A.

Proposals:

- Using other methods to determine the index weight (Analytic Hierarchy Process)

- Providing quantitative assessments for sectors such as population, health; forest fire...

- MIKE and DSSAT are useful, capable of assessing the impact of climate change to flood, salinization and crops.

PUBLICATION OF THE AUTHOR'S RESEARCH PAPERS
RELATING TO THE THESIS

1. **Trần Duy Hiền**, Trần Hồng Thái, Nguyễn Đăng Mậu (2014), “Assessment of Climate change Signals in Da Nang”, Journal of Meteorology and Hydrology (No 639) 10-15.
2. **Trần Duy Hiền**, Trần Hồng Thái (2014), “Assessment of Climate change impact on productivity and growth duration of some agricultural plants in Da Nang”, Journal of Meteorology and Hydrology (No 645) 41-45;
3. **Trần Duy Hiền**, Hoàng Văn Đại, Lê Thị Kim Ngân và Mai Kim Liên (2015), “ Impacts of Climate change and sea level rise on transportation inundation in Da Nang city” (No 658) 56-60.
4. **Trần Duy Hiền**, Trần Hồng Thái, Hoàng Văn Đại, Lê Thị Kim Ngân (2015), “Identifying vulnerability caused by Climate change and sea level rise in transportation and urban area in Da Nang City” Journal of Meteorology and Hydrology (No 660) 05-10.